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# SILVER LAKE, NEW CASTLE COUNTY, DELAWARE. EPA REGION III

Pacific Northwest Environmental Research Laboratory

Prepared for:

National Environmental Research Center

June 1975

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# U.S. ENVIRONMENTAL PROTECTION AGENCY
# NATIONAL EUTROPHICATION SURVEY

**WORKING PAPER SERIES**

REPORT ON

SILVER LAKE

NEW CASTLE COUNTY

DELAWARE

EPA REGION III

WORKING PAPER No. 240

**PACIFIC NORTHWEST ENVIRONMENTAL RESEARCH LABORATORY**

**An Associate Laboratory of the**

**NATIONAL ENVIRONMENTAL RESEARCH CENTER - CORVALLIS, OREGON**

**and**

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REPORT ON

# SILVER LAKE

NEW CASTLE COUNTY

DELAWARE

EPA REGION III

WORKING PAPER No. 240

WITH THE COOPERATION OF THE

DELAWARE DEPARTMENT OF NATURAL RESOURCES

AND ENVIRONMENTAL CONTROL AND THE

DELAWARE NATIONAL GUARD

JUNE 1975

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16. ABSTRACT
Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

17. KEY WORDS AND DOCUMENT ANALYSIS

| a. DESCRIPTORS | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
|---|---|---|
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# REPORT ON SILVER LAKE

## NEW CASTLE COUNTY, DELAWARE, EPA REGION III

by

National Eutrophication Survey

Water and Land Monitoring Branch
Monitoring Applications Laboratory
National Environmental Research Center
Las Vegas, Nevada

and

Eutrophication Survey Branch
Pacific Northwest Environmental Research Laboratory
National Environmental Research Center
Corvallis, Oregon

Working Paper No. 240

OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY

June 1975

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CONTENTS


| | Page |
|---|---|
| Foreword | ii |
| List of Delaware Study Lakes | iv |
| Lake and Drainage Area Map | v |
| Sections | |
| I. Conclusions | 1 |
| II. Lake and Drainage Basin Characteristics | 3 |
| III. Lake Water Quality Summary | 5 |
| IV. Nutrient Loadings | 9 |
| V. Literature Reviewed | 13 |
| VI. Appendices | 14 |

# FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

## OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point source discharge reduction and nonpoint source pollution abatement in lake watersheds.

## ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

## LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin

planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's freshwater lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research and Development, U.S. Environmental Protection Agency) expresses sincere appreciation to the Delaware Division of Water Pollution Control for professional involvement and to the Delaware National Guard for conducting the tributary sampling phase of the Survey.

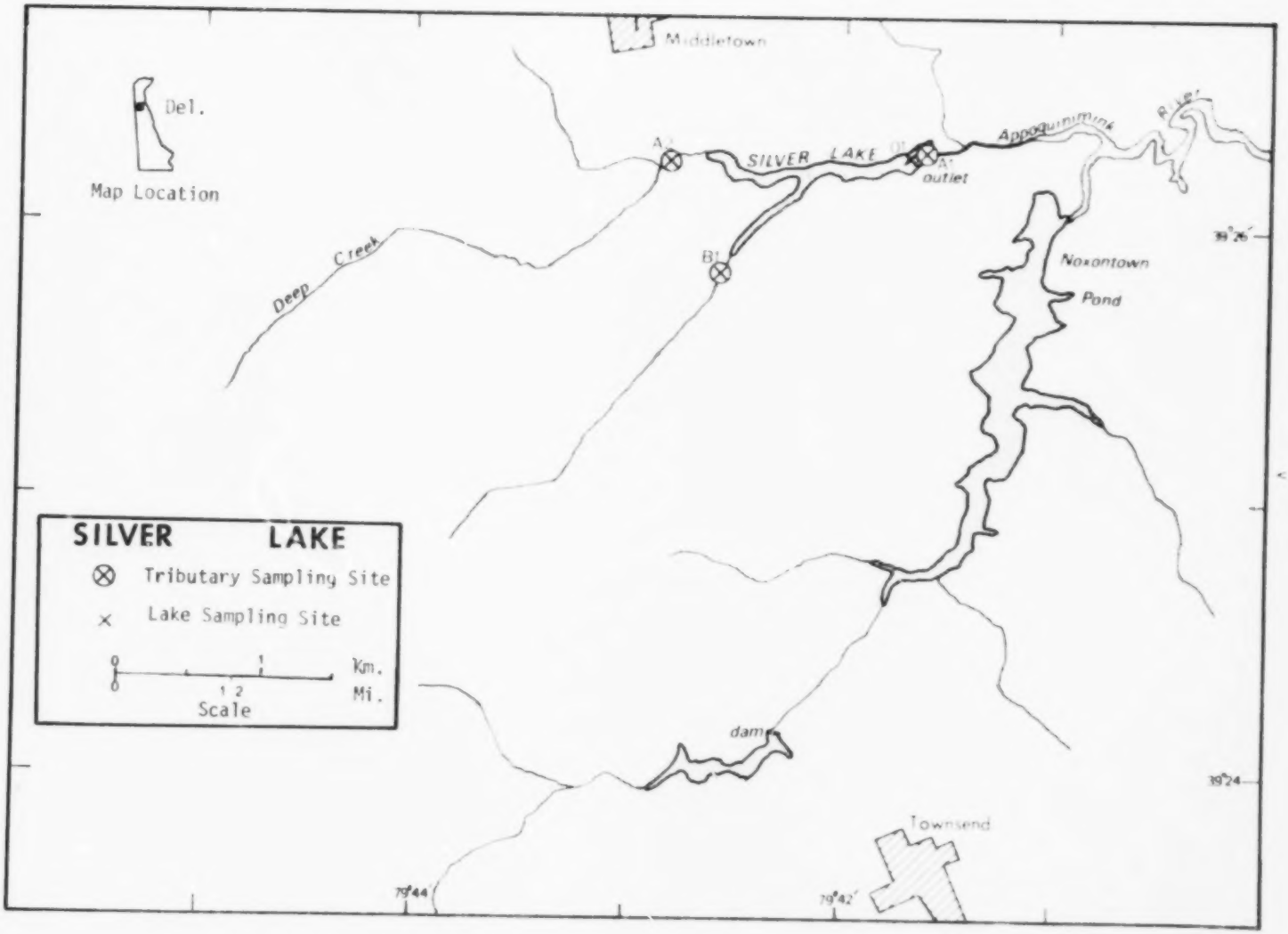
N. D. Vasuki, Director, and R. R. Bartchy, Resource Engineer, of the Delaware Division of Water Pollution Control provided invaluable lake documentation and counsel during the course of the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF DELAWARE

| LAKE NAME | COUNTY |
|---|---|
| Killen Pond | Kent |
| Moores Lake | Kent |
| Noxontown Pond | New Castle |
| Silver Lake | New Castle |
| Williams Pond | Sussex |
| Trussum Pond | Sussex |


Middletown
Del.
Map Location
A'
SILVER LAKE
A'
outlet
Appoquinimink
River
Deep Creek
B'
Noxontown
Pond
SILVER LAKE
Tributary Sampling Site
Lake Sampling Site
0 1 Km.
0 1 2 Mi.
Scale
dam
Townsend
39°26'
39°24'
75°44'
75°42'

SILVER LAKE

STORET NO. 1008

# I. CONCLUSIONS

## A. Trophic Condition:

Silver Lake is classified as eutrophic based upon Survey data. Heavy growths of aquatic weeds (spatterdock and smartweed) clog the upper reaches of the lake. Potential for primary productivity as measured by algal assay control yield, chlorophyll a levels, and nutrient concentrations was high. Dissolved oxygen concentrations were depressed during summer sampling, and water clarity was generally low. Phytoplankton genera identified were generally pollution-tolerant forms.

## B. Rate-Limiting Nutrient:

Algal assay results indicate that at the time of sampling, phosphorus and nitrogen were present in sufficient concentrations that some unidentified nutrient limited growth of the assay alga before either of the major nutrients was exhausted. Lake data concerning the ratios of inorganic nitrogen to orthophosphorus (greater than 46:1 on all three sampling rounds) suggest that phosphorus would become limiting well before available nitrogen was depleted.

C. Nutrient Controllability:

1. Point Sources - The mean annual phosphorus load from point sources was estimated to be 44.3% of the total load reaching Silver Lake. The Middletown wastewater treatment plant contributed 44.2% of the total load.

2. Nonpoint Sources - The mean annual phosphorus load from nonpoint sources was 55.7% of the total load reaching Silver Lake. Measured tributaries accounted for 53.1% of the total phosphorus load, and the remaining drainage areas were estimated to have contributed 2.5%.

The present loading rate of 52.47 g $P/m^2/yr$ is approximately six times the "dangerous" (eutrophic) rate proposed by Vollenweider (in press) for a lake of such volume and detention time. However, Vollenweider's model probably does not apply to water bodies with short hydraulic retention times, and the hydraulic retention time of Silver Lake is only 8 days. Further analysis of surrounding land uses and unknown nutrient sources is needed before recommendations for the improvement of water quality in Silver Lake can be made.

## II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

Lake and drainage basin characteristics are itemized below. Lake surface area was provided by the State of Delaware; mean depth was estimated based on survey data; tributary flow data were provided by the Delaware District Office of the U.S. Geological Survey (USGS) (outlet drainage area includes the lake surface area). Mean hydraulic retention time was obtained by dividing the lake volume by mean flow of the outlet.

Precipitation values are estimated by methods as outlined in National Eutrophication Survey (NES) Working Paper No. 175. A table of metric/English conversions is included as Appendix A.

A. Lake Morphometry:

1. Surface area: 0.15 $km^2$.
2. Mean depth: 1.5 meters.
3. Maximum depth: ? meters.
4. Volume: 0.225 x $10^6$ $m^3$.
5. Mean hydraulic retention time: 8 days.

B. Tributary and Outlet (see Appendix C for flow data):

1. Tributaries -

| Name | Drainage area($km^2$) | Mean flow ($m^3/sec$) |
|---|---|---|
| A(2) Deep Creek | 9.5 | 0.16 |
| B(1) Unnamed Stream | 5.4 | 0.09 |
| Minor tributaries & immediate drainage - | 4.4 | 0.08 |
| Totals | 19.3 | 0.33 |

2. Outlet - A(1) Deep Creek 19.5 0.33

C. Precipitation:

1. Year of sampling: 132.5 centimeters.

2. Mean annual: 104.5 centimeters.

## III. LAKE WATER QUALITY SUMMARY

Silver Lake was sampled three times during the open-water season of 1973 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from one station on the lake and from a number of depths at that station (see map, page v). During each visit, depth-integrated samples were collected from the station for chlorophyll *a* analysis and phytoplankton identification and enumeration. During the first visit, an 18.9-liter depth-integrated sample was composited for algal assays. The maximum depth sampled was 2.4 meters. For a more detailed explanation of NES methods, see NES Working Paper No. 175.

The results obtained are presented in full in Appendix D and are summarized in III A for waters at the surface and at the maximum depth for the sampling site. Results of the phytoplankton counts and chlorophyll *a* determinations are included in III B. Results of the limiting nutrient study are presented in III C.

A. PHYSICAL AND CHEMICAL CHARACTERISTICS

| PARAMETER | ( 4/10/73 ) S*** = 1 N* | RANGE | MEDIAN | MAX DEPTH RANGE (METERS) | ( 7/20/73 ) S*** = 1 N* | RANGE | MEDIAN | MAX DEPTH RANGE (METERS) | ( 9/29/73 ) S*** = 1 N* | RANGE | MEDIAN | MAX DEPTH RANGE (METERS) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TEMPERATURE (DEG CENT) | | | | | | | | | | | | |
| 0.-1.5 M DEPTH | 2 | 12.1- 12.1 | 12.1 | 0.0- 1.2 | 2 | 21.2- 26.2 | 23.7 | 0.0- 1.5 | 2 | 18.6- 20.2 | 19.4 | 0.0- 1.5 |
| MAX DEPTH** | 1 | 12.1- 12.1 | 12.1 | 2.4- 2.4 | 1 | 21.2- 21.2 | 21.2 | 1.5- 1.5 | 1 | 18.6- 18.6 | 18.6 | 1.5- 1.5 |
| DISSOLVED OXYGEN (MG/L) | | | | | | | | | | | | |
| 0.-1.5 M DEPTH | 1 | 9.2- 9.2 | 9.2 | 1.2- 1.2 | 2 | 2.0- 17.8 | 9.9 | 0.0- 1.5 | 1 | 6.5- 6.5 | 6.5 | 0.0- 0.0 |
| MAX DEPTH** | 1 | 9.2- 9.2 | 9.2 | 2.4- 2.4 | 1 | 2.0- 2.0 | 2.0 | 1.5- 1.5 | 0 | ----- ----- | ----- | ----- ----- |
| CONDUCTIVITY (UMHOS) | | | | | | | | | | | | |
| 0.-1.5 M DEPTH | 2 | 200.- 200. | 200. | 0.0- 1.2 | 2 | 217.- 224. | 221. | 0.0- 1.5 | 2 | 222.- 224. | 223. | 0.0- 1.5 |
| MAX DEPTH** | 1 | 195.- 195. | 195. | 2.4- 2.4 | 1 | 217.- 217. | 217. | 1.5- 1.5 | 1 | 222.- 222. | 222. | 1.5- 1.5 |
| PH (STANDARD UNITS) | | | | | | | | | | | | |
| 0.-1.5 M DEPTH | 2 | 7.1- 7.1 | 7.1 | 0.0- 1.2 | 2 | 6.6- 9.7 | 8.1 | 0.0- 1.5 | 1 | 7.7- 7.7 | 7.7 | 0.0- 0.0 |
| MAX DEPTH** | 1 | 7.1- 7.1 | 7.1 | 2.4- 2.4 | 1 | 6.6- 6.6 | 6.6 | 1.5- 1.5 | 0 | ----- ----- | ----- | ----- ----- |
| TOTAL ALKALINITY (MG/L) | | | | | | | | | | | | |
| 0.-1.5 M DEPTH | 2 | 21.- 22. | 22. | 0.0- 1.2 | 2 | 27.- 31. | 29. | 0.0- 1.5 | 1 | 38.- 38. | 38. | 0.0- 0.0 |
| MAX DEPTH** | 1 | 24.- 24. | 24. | 2.4- 2.4 | 1 | 31.- 31. | 31. | 1.5- 1.5 | 0 | ----- ----- | ----- | ----- ----- |
| TOTAL P (MG/L) | | | | | | | | | | | | |
| 0.-1.5 M DEPTH | 2 | 0.244-0.245 | 0.244 | 0.0- 1.2 | 2 | 0.102-0.120 | 0.111 | 0.0- 1.5 | 1 | 0.211-0.211 | 0.211 | 0.0- 0.0 |
| MAX DEPTH** | 1 | 0.247-0.247 | 0.247 | 2.4- 2.4 | 1 | 0.120-0.120 | 0.120 | 1.5- 1.5 | 0 | ----- ----- | ----- | ----- ----- |
| DISSOLVED ORTHO P (MG/L) | | | | | | | | | | | | |
| 0.-1.5 M DEPTH | 2 | 0.097-0.099 | 0.098 | 0.0- 1.2 | 2 | 0.015-0.049 | 0.032 | 0.0- 1.5 | 1 | 0.101-0.101 | 0.101 | 0.0- 0.0 |
| MAX DEPTH** | 1 | 0.096-0.096 | 0.096 | 2.4- 2.4 | 1 | 0.049-0.049 | 0.049 | 1.5- 1.5 | 0 | ----- ----- | ----- | ----- ----- |
| NO2+NO3 (MG/L) | | | | | | | | | | | | |
| 0.-1.5 M DEPTH | 2 | 2.900-5.200 | 4.050 | 0.0- 1.2 | 2 | 4.100-4.500 | 4.300 | 0.0- 1.5 | 1 | 4.470-4.470 | 4.470 | 0.0- 0.0 |
| MAX DEPTH** | 1 | 4.500-4.500 | 4.500 | 2.4- 2.4 | 1 | 4.500-4.500 | 4.500 | 1.5- 1.5 | 0 | ----- ----- | ----- | ----- ----- |
| AMMONIA (MG/L) | | | | | | | | | | | | |
| 0.-1.5 M DEPTH | 2 | 0.370-0.370 | 0.370 | 0.0- 1.2 | 2 | 0.090-0.310 | 0.200 | 0.0- 1.5 | 1 | 0.220-0.220 | 0.220 | 0.0- 0.0 |
| MAX DEPTH** | 1 | 0.380-0.380 | 0.380 | 2.4- 2.4 | 1 | 0.310-0.310 | 0.310 | 1.5- 1.5 | 0 | ----- ----- | ----- | ----- ----- |
| KJELDAHL N (MG/L) | | | | | | | | | | | | |
| 0.-1.5 M DEPTH | 2 | 1.000-1.000 | 1.000 | 0.0- 1.2 | 2 | 0.800-1.100 | 0.950 | 0.0- 1.5 | 1 | 1.700-1.700 | 1.700 | 0.0- 0.0 |
| MAX DEPTH** | 1 | 0.900-0.900 | 0.900 | 2.4- 2.4 | 1 | 0.800-0.800 | 0.800 | 1.5- 1.5 | 0 | ----- ----- | ----- | ----- ----- |
| SECCHI DISC (METERS) | | | | | | | | | | | | |
| | 1 | 0.5- 0.5 | 0.5 | | 1 | 0.9- 0.9 | 0.9 | | 1 | 1.3- 1.3 | 1.3 | |

* N = NO. OF SAMPLES
** MAXIMUM DEPTH SAMPLED AT EACH SITE
*** S = NO. OF SITES SAMPLED ON THIS DATE

B. Biological Characteristics:

1. Phytoplankton -

| Sampling Data | Dominant Genera | | Algal Units per ml |
|---|---|---|---|
| 07/20/73 | 1. | Flagellates | 11,031 |
| | 2. | Micractinium | 2,464 |
| | 3. | Schroederia | 1,702 |
| | 4. | Nitzschia | 1,408 |
| | 5. | Green cells | 821 |
| | | Other genera | 4,168 |
| | | Total | 21,594 |
| 09/29/73 | 1. | Scenedesmus | 1,698 |
| | 2. | Flagellates | 609 |
| | 3. | Coelastrum | 279 |
| | 4. | Cosmerium | 101 |
| | 5. | Staurastrum | 101 |
| | | Other genera | 227 |
| | | Total | 3,015 |

2. Chlorophyll *a* -

| Sampling Date | Station Number | Chlorophyll a (micrograms/liter) |
|---|---|---|
| 04/10/73 | 1 | 8.6 |
| 07/20/73 | 1 | 52.8 |
| 09/29/73 | 1 | 18.7 |

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

| Spike(mg/l) | Ortho P Conc.(mg/l) | Inorganic N Conc.(mg/l) | Maximum yield (mg/l-dry wt.) |
|---|---|---|---|
| Control | 0.128 | 4.664 | 30.2 |
| 0.05 P | 0.178 | 4.664 | 31.1 |
| 0.05 P + 1.0 N | 0.178 | 5.664 | 29.9 |
| 1.00 N | 0.128 | 5.664 | 25.6 |

2. Discussion -

The control yield of the assay alga, Selenastrum capricornutum, indicates that the potential for primary production in Silver Lake was high at the time of sampling. Spikes with phosphorus and nitrogen alone, or simultaneous addition of these two nutrients failed to enhance the control yield. It appears that those major nutrients are present in sufficient concentrations to allow reduction of some undetermined nutritional element to levels which are limiting to lake productivity.

The ratios of the mean inorganic nitrogen to ortho-phosphorus for all three sampling dates were greater than 46:1, suggesting that phosphorus could become limiting while nitrogen still remained at high levels.

## IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the Delaware National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff month of March when two samples were collected. Sampling was begun in April 1973 and was completed in March 1974.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Delaware District Office of the USGS for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of the USGS computer program for calculating stream loadings. Nutrient loads indicated for tributaries are those measured minus known point source loads, if any.

Nutrient loadings for unsampled "minor tributaries and immediate drainage" ("ZZ" of USGS) were estimated by using the mean annual concentrations in Unnamed Stream at Station B(1) and mean annual ZZ flow.

The operator of the Middletown wastewater treatment plant provided monthly effluent samples and corresponding flow data.

A. Waste Sources:

1. Known municipal -

| Name | Population Served | Treatment | Mean Flow ($m^3/d \times 103$) | Receiving Water |
|---|---|---|---|---|
| Middletown | 2,644 | Trickling Filter | 0.852 | Appoquinimink River |

2. Known industrial - None

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

| Source | kg P/yr | % of total |
|---|---|---|
| a. Tributaries (nonpoint load) - | | |
| A(2) Deep Creek | 2,440 | 50.1 |
| B(1) Unnamed Stream | 145 | 3.0 |
| b. Minor tributaries & immediate drainage (nonpoint load) - | 120 | 2.5 |
| c. Known municipal STP's - | | |
| Middletown | 2,155 | 44.2 |
| d. Septic tanks* - | 5 | 0.1 |
| e. Known industrial - None | | |
| f. Direct precipitation** - | 5 | 0.1 |
| Totals | 4,870 | 100.0 |

2. Outputs - Deep Creek 2,520

3. Net annual P accumulation - 2,350

*Estimate based on 15 lakeshore residences.
**Estimated (see NES Working Paper No. 175).

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

| Source | kg N/yr | % of total |
|---|---|---|
| a. Tributaries (nonpoint load) - | | |
| A(2) Deep Creek | 31,110 | 41.0 |
| B(1) Unnamed Stream | 20,375 | 26.9 |
| b. Minor tributaries & immediate drainage (nonpoint load) - | 19,160 | 25.3 |
| c. Known municipal STP's - | | |
| Middletown | 4,845 | 6.4 |
| d. Septic tanks* - | 160 | 0.2 |
| e. Known industrial - None | | |
| f. Direct precipitation** - | 165 | 0.2 |
| Totals | 75,815 | 100.0 |

2. Outputs - Deep Creek 58,835

3. Net annual N accumulation - 16,980

D. Mean Annual Nonpoint Nutrient Export by Subdrainage Area:

| Tributary | kg P/km$^2$/yr | kg N/km$^2$/yr |
|---|---|---|
| A(2) Deep Creek | 257 | 3,275 |
| B(1) Unnamed Stream | 27 | 3,773 |

*Estimate based on 15 lakeshore residences.
**Estimated (see NES Working Paper No. 175).

E. Yearly Loading Rates:

In the following table, the existing phosphorus loading rates are compared to those proposed by Vollenweider (in press). Essentially, his "dangerous" rate is the rate at which the receiving waters would become eutrophic or remain eutrophic; his "permissible" rate is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic rate would be considered one between "dangerous" and "permissible."

| | Total Yearly Phosphorus Loading Rate ($grams/m^2/year$) |
|---|---|
| Estimated loading rate for Silver Lake | 32.47 |
| Vollenweider's "dangerous" or eutrophic rate | 4.88 |
| Vollenweider's "permissible" or oligotrophic rate | 2.44 |

## V. LITERATURE REVIEWED

Ketelle, Martha J. and Paul D. Uttormark. 1971. "Problem Lakes in the United States." U.S. Environmental Protection Agency Project #16010 EHR. Univeristy of Wisconsin, Madison, Wisconsin.

Lesser, Charles A. 1966. "Aquatic Vegetation Survey; Federal Aid in Fish Restoration." Project #F-21-R. Delaware Fish and Game Commission, Dover, Delaware.

U.S. Environmental Protection Agency. 1975. "National Eutrophication Survey Methods 1973-1976." Working Paper No. 175. NERC, Las Vegas, Nevada, and PNERL, Corvallis, Oregon.

Vollenweider, Richard A. (in press). "Input-Output Models." Schweiz. Z. Hydrol.

## CONVERSION FACTORS

Hectares x 2.471 = acres

Meters x 3.281 = feet

Cubic meters x $8.107 \times 10^{-4}$ = acre feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX B

PARAMETRIC RANKINGS OF LAKES

SAMPLED BY NES IN 1973

STATE OF DELAWARE

LAKE DATA TO BE USED IN RANKINGS

| LAKE CODE | LAKE NAME | MEDIAN TOTAL P | MEDIAN INORG N | 500-MEAN SEC | MEAN CHLORA | 15-MIN DO | MEDIAN DISS ORTHO P |
|---|---|---|---|---|---|---|---|
| 1002 | KILLEN POND | 0.170 | 1.610 | 479.333 | 116.200 | 12.000 | 0.042 |
| 1005 | MOORES LAKE | 0.245 | 2.400 | 472.667 | 81.267 | 4.700 | 0.071 |
| 1007 | NOAONTOWN POND | 0.160 | 0.530 | 478.833 | 37.600 | 10.400 | 0.016 |
| 1008 | SILVER LAKE | 0.227 | 4.750 | 465.667 | 26.700 | 13.000 | 0.095 |
| 1009 | WILLIAMS POND | 0.042 | 2.010 | 449.333 | 30.100 | 8.800 | 0.010 |
| 1010 | TRUSSUM POND | 0.038 | 1.280 | 464.000 | 5.100 | 5.800 | 0.011 |

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

| LAKE CODE | LAKE NAME | MEDIAN TOTAL P | MEDIAN INORG N | 500-MEAN SEC | MEAN CHLORA | 15-MIN DO | MEDIAN DISS ORTHO P |
|---|---|---|---|---|---|---|---|
| 1002 | KILLEN POND | 40 ( 2) | 60 ( 3) | 0 ( 0) | 0 ( 0) | 20 ( 1) | 40 ( 2) |
| 1005 | MOORES LAKE | 0 ( 0) | 20 ( 1) | 40 ( 2) | 20 ( 1) | 100 ( 5) | 20 ( 1) |
| 1007 | NOXONTOWN POND | 60 ( 3) | 100 ( 5) | 20 ( 1) | 40 ( 2) | 40 ( 2) | 60 ( 3) |
| 1008 | SILVER LAKE | 20 ( 1) | 0 ( 0) | 60 ( 3) | 80 ( 4) | 0 ( 0) | 0 ( 0) |
| 1009 | WILLIAMS POND | 80 ( 4) | 40 ( 2) | 100 ( 5) | 60 ( 3) | 60 ( 3) | 100 ( 5) |
| 1010 | TRUGSUM POND | 100 ( 5) | 80 ( 4) | 80 ( 4) | 100 ( 5) | 80 ( 4) | 80 ( 4) |

# APPENDIX C

# TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR DELAWARE 10/20/75

LAKE CODE 1008 SILVER LAKE

TOTAL DRAINAGE AREA OF LAKE(SQ MI) 7.51

| TRIBUTARY | SUB-DRAINAGE AREA(SQ MI) | NORMALIZED FLOWS(CFS) JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | MEAN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1008A1 | 7.51 | 14.50 | 15.50 | 17.20 | 12.90 | 10.00 | 10.20 | 8.80 | 11.60 | 9.60 | 7.60 | 10.30 | 12.00 | 11.66 |
| 1008A2 | 3.68 | 7.00 | 7.50 | 8.30 | 6.20 | 4.70 | 4.90 | 4.30 | 5.60 | 4.60 | 3.60 | 5.00 | 5.80 | 5.61 |
| 1008B1 | 2.08 | 3.90 | 4.20 | 4.70 | 3.50 | 2.70 | 2.80 | 2.40 | 3.10 | 2.60 | 2.00 | 2.80 | 3.20 | 3.15 |
| 1008ZZ | 1.75 | 3.60 | 3.80 | 4.20 | 3.20 | 2.60 | 2.50 | 2.10 | 2.90 | 2.40 | 2.00 | 2.50 | 3.00 | 2.90 |

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 7.51
SUM OF SUB-DRAINAGE AREAS = 7.51

TOTAL FLOW IN = 140.20
TOTAL FLOW OUT = 140.20

MEAN MONTHLY FLOWS AND DAILY FLOWS(CFS)

| TRIBUTARY | MONTH | YEAR | MEAN FLOW | DAY | FLOW | DAY | FLOW | DAY | FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 1008A1 | 4 | 73 | 30.00 | 28 | 29.00 | | | | |
| | 5 | 73 | 18.50 | 20 | 18.00 | | | | |
| | 6 | 73 | 48.00 | 25 | 13.00 | | | | |
| | 7 | 73 | 22.00 | 23 | 12.00 | | | | |
| | 8 | 73 | 22.00 | 20 | 9.50 | | | | |
| | 9 | 73 | 9.60 | 16 | 10.00 | | | | |
| | 10 | 73 | 17.00 | 28 | 8.00 | | | | |
| | 11 | 73 | 10.00 | 16 | 9.60 | | | | |
| | 12 | 73 | 30.00 | 4 | 9.60 | | | | |
| | 1 | 74 | 18.00 | 8 | 12.00 | | | | |
| | 2 | 74 | 12.00 | 5 | 8.80 | 22 | 12.00 | | |
| | 3 | 74 | 20.00 | 11 | 10.00 | 22 | 46.00 | | |
| 1008A2 | 4 | 73 | 14.00 | 28 | 14.00 | | | | |
| | 5 | 73 | 9.00 | 20 | 8.70 | | | | |
| | 6 | 73 | 22.80 | 25 | 6.20 | | | | |
| | 7 | 73 | 10.50 | 23 | 5.80 | | | | |
| | 8 | 73 | 10.80 | 20 | 4.60 | | | | |
| | 9 | 73 | 4.60 | 16 | 4.90 | | | | |
| | 10 | 73 | 8.00 | 28 | 3.90 | | | | |
| | 11 | 73 | 4.90 | 16 | 4.60 | | | | |
| | 12 | 73 | 14.00 | 4 | 4.60 | | | | |
| | 1 | 74 | 8.80 | 8 | 6.00 | | | | |
| | 2 | 74 | 5.90 | 5 | 4.30 | 22 | 5.90 | | |
| | 3 | 74 | 9.90 | 11 | 4.80 | 22 | 23.00 | | |

19.61

TRIBUTARY FLOW INFORMATION FOR DELAWARE 10/20/75

LAKE CODE 100B SILVER LAKE

MEAN MONTHLY FLOWS AND DAILY FLOWS(CFS)

| TRIBUTARY | MONTH | YEAR | MEAN FLOW | DAY | FLOW | DAY | FLOW | DAY | FLOW |
|---|---|---|---|---|---|---|---|---|---|
| 100881 | 4 | 73 | 8.20 | 28 | 8.20 | | | | |
| | 5 | 73 | 5.00 | 20 | 4.90 | | | | |
| | 6 | 73 | 13.90 | 25 | 3.50 | | | | |
| | 7 | 73 | 4.90 | 23 | 3.20 | | | | |
| | 8 | 73 | 6.00 | 20 | 2.60 | | | | |
| | 9 | 73 | 2.60 | 16 | 2.80 | | | | |
| | 10 | 73 | 4.60 | 28 | 2.20 | | | | |
| | 11 | 73 | 2.80 | 16 | 2.60 | | | | |
| | 12 | 73 | 8.20 | 4 | 2.60 | | | | |
| | 1 | 74 | 5.00 | 8 | 3.40 | | | | |
| | 2 | 74 | 3.20 | 5 | 2.40 | 22 | 3.20 | | |
| | 3 | 74 | 5.60 | 11 | 2.70 | 22 | 13.00 | | |
| 100822 | 4 | 73 | 6.70 | 28 | 6.70 | | | | |
| | 5 | 73 | 4.30 | 20 | 4.20 | | | | |
| | 6 | 73 | 10.90 | 25 | 3.00 | | | | |
| | 7 | 73 | 5.00 | 23 | 2.80 | | | | |
| | 8 | 73 | 5.20 | 20 | 2.20 | | | | |
| | 9 | 73 | 2.20 | 16 | 2.40 | | | | |
| | 10 | 73 | 3.80 | 28 | 1.90 | | | | |
| | 11 | 73 | 2.40 | 16 | 2.20 | | | | |
| | 12 | 73 | 6.70 | 4 | 2.20 | | | | |
| | 1 | 74 | 4.20 | 8 | 2.90 | | | | |
| | 2 | 74 | 2.80 | 5 | 2.10 | 22 | 2.80 | | |
| | 3 | 74 | 4.80 | 11 | 2.30 | 22 | 11.00 | | |

# APPENDIX D

# PHYSICAL AND CHEMICAL DATA

STORET RETRIEVAL DATE 75/10/16

100801
39 26 15.0 075 41 40.0
SILVER LAKE
10 DELAWARE

11EPALES 2111202
3 0010 FEET DEPTH

| DATE FROM TO | TIME OF DAY | DEPTH FEET | 00010 WATER TEMP CENT | 00300 DO MG/L | 00077 TRANSP SECCHI INCHES | 00094 CNDUCTVY FIELD MICROMHO | 00400 PH SU | 00410 T ALK CACO3 MG/L | 00610 NH3-N TOTAL MG/L | 00625 TOT KJEL N MG/L | 00630 NO2&NO3 N-TOTAL MG/L | 00671 PHOS-DIS ORTHO MG/L P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 73/04/10 | 10 | 15 0000 | 12.1 | | 18 | 200 | 7.10 | 22 | 0.370 | 1.000 | 2.900 | 0.097 |
| | 10 | 15 0004 | 12.1 | 9.2 | | 200 | 7.10 | 21 | 0.370 | 1.000 | 5.200 | 0.099 |
| | 10 | 15 0008 | 12.1 | 9.2 | | 195 | 7.10 | 24 | 0.380 | 0.900 | 4.500 | 0.096 |
| 73/07/20 | 12 | 10 0000 | 26.2 | 17.8 | 35 | 224 | 9.70 | 27 | 0.090 | 1.100 | 4.100 | 0.015 |
| | 12 | 10 0005 | 21.2 | 2.0 | | 217 | 6.60 | 31 | 0.310 | 0.800 | 4.500 | 0.049 |
| 73/09/29 | 10 | 10 0000 | 20.2 | 6.5 | 50 | 224 | 7.70 | 38 | 0.220 | 1.700 | 4.470 | 0.101 |
| | 10 | 10 0005 | 18.6 | | | 222 | | | | | | |

22.

| DATE FROM TO | TIME OF DAY | DEPTH FEET | 00665 PHOS-TOT MG/L P | 32217 CHLRPHYL A UG/L |
|---|---|---|---|---|
| 73/04/10 | 10 | 15 0000 | 0.245 | 8.6 |
| | 10 | 15 0004 | 0.244 | |
| | 10 | 15 0008 | 0.247 | |
| 73/07/20 | 12 | 10 0000 | 0.102 | 52.8 |
| | 12 | 10 0005 | 0.120 | |
| 73/09/29 | 10 | 10 0000 | 0.211 | 18.7 |

# APPENDIX E

# TRIBUTARY AND WASTEWATER TREATMENT PLANT DATA

STORET RETRIEVAL DATE 75/10/16

1008A1
39 26 30.0 075 41 30.0
DEEP CREEK
10 7.5 MIDDLETOWN
0/SILVER LAKE
BRDG 2 MI SE OF MIDDLETOWN
11EPALES 2111204
4 0000 FEET DEPTH

| DATE FROM TO | TIME OF DAY | DEPTH FEET | 00630 NO2&NO3 N-TOTAL MG/L | 00625 TOT KJEL N MG/L | 00610 NH3-N TOTAL MG/L | 00671 PHOS-DIS ORTHO MG/L P | 00665 PHOS-TOT MG/L P |
|---|---|---|---|---|---|---|---|
| 73/04/28 | 09 40 | | 4.800 | 1.150 | 0.260 | 0.105 | 0.200 |
| 73/05/20 | 13 35 | | 4.850 | 0.600 | 0.198 | 0.115 | 0.200 |
| 73/06/25 | 13 30 | | 3.600 | 2.300 | 0.067 | 0.058 | 0.230 |
| 73/07/23 | 09 25 | | 4.500 | 1.260 | 0.080 | 0.048 | 0.150 |
| 73/08/20 | 10 45 | | | 2.200 | 0.220 | 0.034 | 0.180 |
| 73/09/16 | 16 45 | | 3.300 | 1.760 | 0.510 | 0.063 | 0.180 |
| 73/10/28 | 14 00 | | 4.600 | 1.650 | 0.046 | 0.066 | 0.230 |
| 73/11/16 | 14 00 | | 5.000 | 1.050 | 0.210 | 0.115 | 0.315 |
| 73/12/04 | 09 40 | | 4.620 | 1.000 | 0.480 | 0.076 | 0.230 |
| 74/01/08 | 14 05 | | 5.000 | 1.100 | 0.528 | 0.120 | 0.290 |
| 74/02/05 | 15 00 | | 6.000 | 0.900 | 0.250 | 0.100 | 0.260 |
| 74/03/11 | 10 00 | | 5.200 | 1.300 | 0.185 | 0.045 | 0.230 |
| 74/03/22 | 10 30 | | 4.800 | 1.200 | 0.180 | 0.055 | 0.185 |

24.

STORET RETRIEVAL DATE 75/10/16

100MA2
3+ 26 00.0 075 41 00.0
DEEP CREEK
10 7.5 MIDDLETOWN
I/SILVER LAKE
ST RT 71 BRDG S EDGE OF MIDDLETON
11EPALES 211120+
4 0000 FEET DEPTH

| DATE FROM TO | TIME OF DAY | DEPTH FEET | 00630 NO2&NO3 N-TOTAL MG/L | 00625 TOT KJEL N MG/L | 00610 NH3-N TOTAL MG/L | 00671 PHOS-DIS ORTHO MG/L P | 00665 PHOS-TOT MG/L P |
|---|---|---|---|---|---|---|---|
| 73/04/28 | 08 30 | | 4.900 | 1.760 | 0.430 | 0.273 | 0.540 |
| 73/05/20 | 12 40 | | 6.050 | 1.540 | 0.730 | 0.380 | 0.700 |
| 73/06/25 | 12 30 | | 6.200 | 1.320 | 0.590 | 0.790 | 1.000 |
| 73/07/23 | 09 05 | | 6.300 | 0.380 | 0.189 | 0.420 | 0.600 |
| 73/08/20 | 09 55 | | | 0.360 | 0.350 | 0.500 | 0.660 |
| 73/09/16 | 15 30 | | 4.900 | 2.100 | 1.080 | 0.690 | 0.850 |
| 73/10/28 | 13 30 | | 6.400 | 2.700 | 2.100 | 3.230 | |
| 73/11/16 | 14 10 | | 5.700 | 1.050 | 0.580 | 0.850 | 1.100 |
| 73/12/04 | 09 15 | | 5.600 | 1.600 | 0.990 | 0.850 | 1.050 |
| 74/01/08 | 13 30 | | 6.400 | 1.900 | 1.300 | 0.756 | 0.960 |
| 74/02/05 | 14 15 | | 6.300 | 2.100 | 1.100 | 0.570 | 0.970 |
| 74/03/11 | 09 10 | | 6.100 | 1.700 | 0.560 | 0.740 | 0.940 |
| 74/03/22 | 09 50 | | 5.200 | 2.600 | 0.315 | 0.400 | 0.700 |

STORET RETRIEVAL DATE 75/10/16

100881
39 26 00.0 075 42 30.0
UNNAMED STREAM
10 7.5 MIDDLETOWN
T/SILVER LAKE
ST HWY 71 BRDG 0.75 MI S OF MIDDLETOWN
11EPALES 2111204
4 0000 FEET DEPTH

| DATE FROM TO | TIME OF DAY | DEPTH FEET | 00630 NO2&NO3 N-TOTAL MG/L | 00625 TOT KJEL N MG/L | 00610 NH3-N TOTAL MG/L | 00671 PHOS-DIS ORTHO MG/L P | 00665 PHOS-TOT MG/L P |
|---|---|---|---|---|---|---|---|
| 73/04/28 | 08 | 50 | 6.100 | 1.100 | 0.126 | 0.033 | 0.095 |
| 73/05/20 | 12 | 55 | 7.150 | 0.150 | 0.113 | 0.012 | 0.050 |
| 73/06/25 | 12 | 40 | 8.000 | | 0.076 | 0.014 | 0.040 |
| 73/07/23 | 09 | 15 | 7.600 | 0.100K | 0.052 | 0.022 | 0.040 |
| 73/08/20 | 10 | 10 | | 1.500 | 0.069 | 0.032 | 0.050 |
| 73/09/16 | 16 | 10 | 7.350 | | 0.069 | 0.024 | 0.047 |
| 73/10/28 | 14 | 35 | 8.500 | 0.100K | 0.059 | 0.017 | 0.060 |
| 73/11/16 | 15 | 10 | 7.900 | 0.100K | 0.044 | 0.020 | 0.040 |
| 73/12/04 | 09 | 20 | 8.400 | 0.100K | 0.048 | 0.016 | 0.020 |
| 74/01/08 | 13 | 35 | 8.300 | 0.500 | 0.065 | 0.015 | 0.025 |
| 74/02/05 | 15 | 30 | 8.500 | 0.100 | 0.030 | 0.007 | 0.020 |
| 74/03/11 | 09 | 20 | 2.800 | 0.700 | 0.180 | 0.030 | 0.065 |
| 74/03/22 | 10 | 00 | 7.300 | 0.600 | 0.110 | 0.015 | 0.060 |

26

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/10/16

1009A1
38 38 30.0 075 36 30.0
CLEAR CREEK-WILLIAMS POND OUTLET
10 7.5 SEAFORD EAST
0/WILLIAMS POND
BRDG IN EASTERN EDGE OF SEAFORD
11EPALES 2111204
4 0000 FEET DEPTH

| DATE FROM TO | TIME OF DAY | DEPTH FEET | 00630 NO2&NO3 N-TOTAL MG/L | 00625 TOT KJEL N MG/L | 00610 NH3-N TOTAL MG/L | 00671 PHOS-DIS ORTHO MG/L P | 00665 PHOS-TOT MG/L P |
|---|---|---|---|---|---|---|---|
| 73/04/28 | 11 01 | | 2.200 | 0.480 | 0.048 | 0.011 | 0.040 |
| 73/05/20 | 09 00 | | 1.420 | 0.890 | 0.032 | 0.008 | 0.035 |
| 73/06/23 | 09 50 | | 0.360 | 0.690 | 0.048 | 0.008 | 0.030 |
| 73/07/22 | 08 30 | | 0.069 | 1.000 | 0.013 | 0.012 | 0.075 |
| 73/08/18 | 09 40 | | | 1.320 | 0.019 | 0.023 | 0.095 |
| 73/09/23 | 13 10 | | 1.800 | 0.940 | 0.098 | 0.010 | 0.055 |
| 73/10/28 | 09 00 | | 1.360 | 0.700 | 0.044 | 0.012 | 0.060 |
| 73/11/10 | 10 45 | | 1.360 | 0.575 | 0.028 | 0.011 | 0.032 |
| 73/12/01 | 09 10 | | 1.760 | 0.400 | 0.032 | 0.008 | 0.040 |
| 74/01/05 | 09 25 | | 3.200 | 0.500 | 0.064 | 0.024 | 0.045 |
| 74/02/05 | | | 4.000 | 0.400 | 0.057 | 0.020 | 0.020 |
| 74/03/09 | 12 15 | | 3.200 | 0.800 | 0.035 | 0.010 | 0.025 |
| 74/03/25 | 10 00 | | 2.800 | 0.700 | 0.020 | 0.015 | 0.035 |

STORET RETRIEVAL DATE 75/10/16

1008BA TF1008BA P002644*
39 26 45.0 075 42 15.0
MIDDLETOWN
10 7.5 MIDDLETOWN
T/SILVER LAKE
APPOQUINIMINK RIVER
11EPALES 2141204
4 0000 FEET DEPTH

| DATE FROM TO | TIME OF DAY | DEPTH FEET | 00630 NO2&NO3 N-TOTAL MG/L | 00625 TOT KJEL N MG/L | 00610 NH3-N TOTAL MG/L | 00671 PHOS-DIS ORTHO MG/L P | 00665 PHOS-TOT MG/L P | 50051 FLOW RATE INST MGD | 50053 CONDUIT FLOW-MGD MONTHLY |
|---|---|---|---|---|---|---|---|---|---|
| 73/06/05 | 07 00 | P | | | | | | | |
| CP(T)- | | | 6.700 | 8.100 | 0.530 | 8.750 | 9.600 | 0.261 | 0.238 |
| 73/06/05 | 16 00 | | | | | | | | |
| | 17 00 | P | | | | | | | |
| CP(T)- | | | 6.700 | 8.700 | 0.910 | 8.800 | 9.500 | 0.261 | 0.238 |
| 73/06/06 | 07 00 | | | | | | | | |
| 73/07/12 | 07 00 | P | | | | | | | |
| CP(T)- | | | 4.100 | 2.100 | 0.340 | 1.900 | 2.650 | 0.262 | 0.233 |
| 73/07/13 | 07 00 | | | | | | | | |
| 73/08/09 | 07 00 | P | | | | | | | |
| CP(T)- | | | 0.096 | 0.160 | 0.138 | 0.070 | 2.500 | 0.261 | 0.232 |
| 73/08/10 | 07 00 | | | | | | | | |
| 73/09/19 | 07 00 | P | | | | | | | |
| CP(T)- | | | 4.640 | 14.800 | 4.600 | 4.500 | 5.800 | 0.229 | 0.243 |
| 73/09/20 | 07 00 | | | | | | | | |
| 73/10/09 | 07 00 | P | | | | | | | |
| CP(T)- | | | 8.000 | 8.700 | 3.100 | 8.000 | 9.500 | 0.216 | 0.242 |
| 73/10/10 | 07 00 | | | | | | | | |
| 73/11/14 | 07 00 | P | | | | | | | |
| CP(T)- | | | 5.200 | 16.500 | 5.000 | 8.300 | 9.400 | 0.229 | 0.243 |
| 73/11/15 | 07 00 | | | | | | | | |
| 73/12/12 | 09 00 | P | | | | | | | |
| CP(T)- | | | 6.900 | 21.000 | 7.600 | 6.500 | 7.800 | 0.202 | 0.197 |
| 73/12/13 | 09 00 | | | | | | | | |
| 74/01/13 | 09 00 | | 7.500 | 8.300 | 1.680 | 5.400 | 6.600 | 0.155 | 0.210 |
| 74/02/12 | 11 00 | | 7.040 | 21.000 | 4.800 | 6.600 | 10.500 | 0.208 | 0.199 |
| 74/03/12 | 09 00 | | 6.500 | 4.100 | 0.660 | 4.300 | 5.100 | 0.192 | 0.286 |
| 74/04/10 | 09 00 | | 1.760 | 6.200 | 0.870 | 3.700 | 4.400 | 0.180 | 0.186 |
| 74/05/08 | 09 00 | | 4.300 | 19.000 | 7.600 | 5.700 | 6.850 | 0.180 | 0.179 |

28